Survey of global convection overshooting tropopause using first year GPM observations

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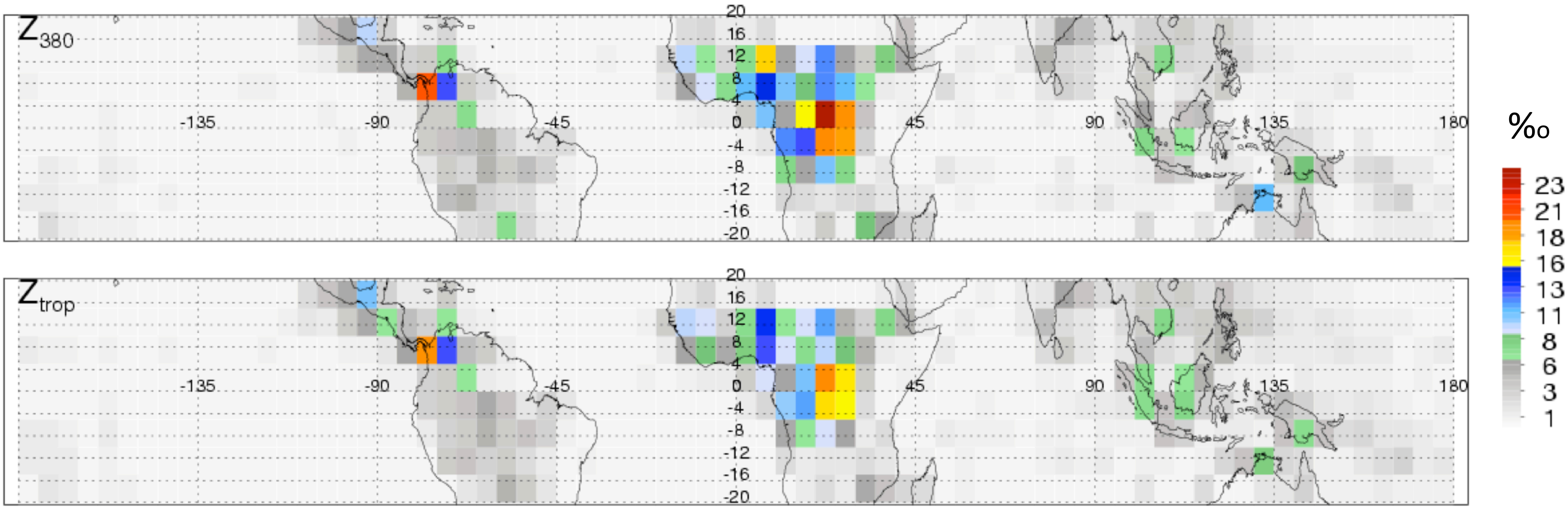
Global distribution of intense convection penetrating tropical tropopause

- Liu and Zipser, 2005

Overshooting area distribution from 5 years of TRMM PR



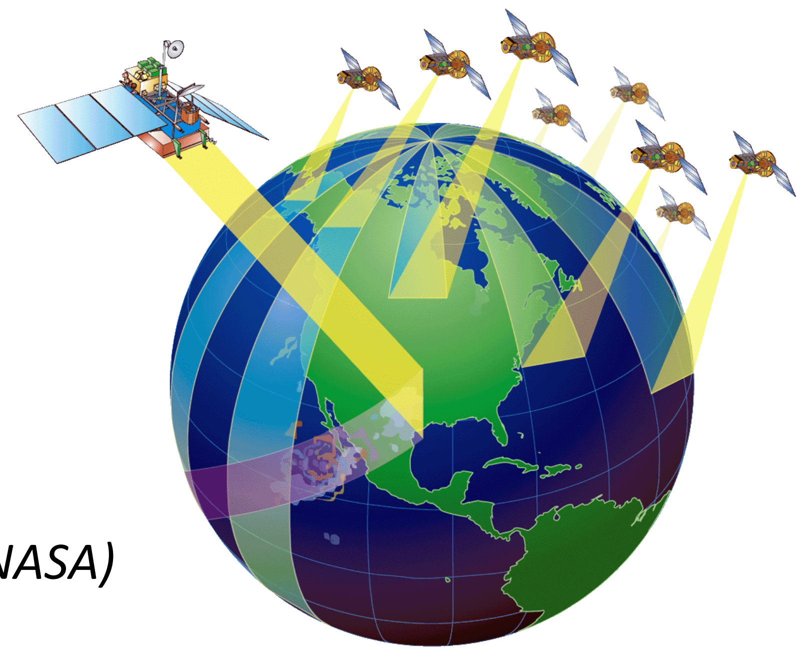
Congo and Panama are two hotspots for overshooting convection

GPM - Successor of TRMM

Core Satellite launched 2014-02-27

- *Non-sun-synchronous orbit (full diurnal cycle)*
  ~ 65° inclination (65°S-65°N ~ 91% of globe)
  ~400 km altitude
- *Dual frequency radar (NASDA)*
  Ku-Ka Bands (13.6-35 GHz)
  ~ 4 km horizontal resolution
  ~250 m vertical resolution
  ~ 18 dBZ sensitivity

Multifrequency passive microwave radiometer (NASA)
10.7, 19, 22, 37, 89, 150, 183 GHz

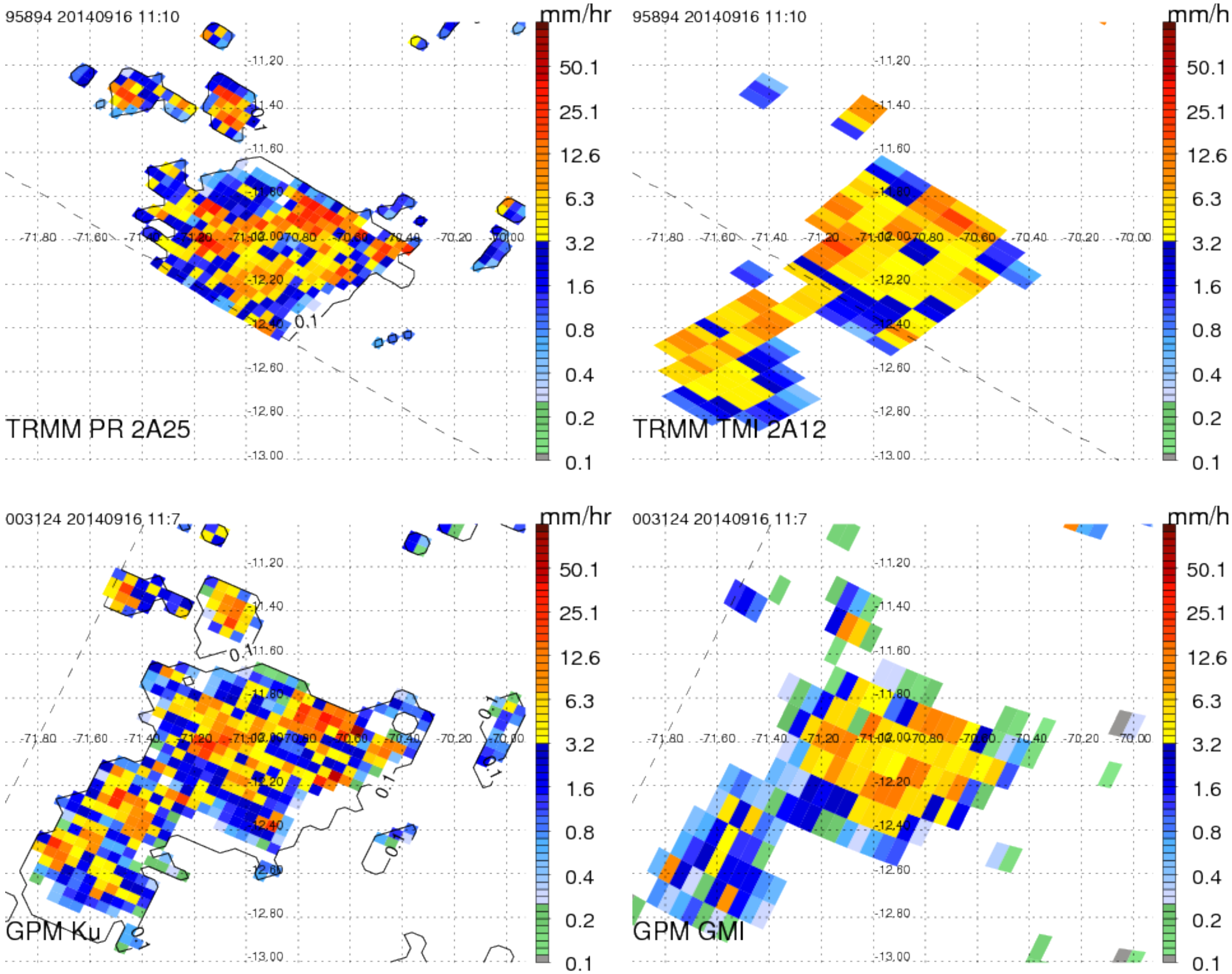


Motivation: How about the overshooting storms in extratropics ?

Grouping Precipitation Features from TRMM and GPM

TRMM radar

TRMM Passive Microwave radiometer



GPM radar

GPM Passive Microwave radiometer

GPM PF definitions and 1 + year inventory

	Definitions of precipitation features
Kurpf	area with Ku near surface precipitation rate > 0 (Normal Swath)
karpf	area with Ka near surface precipitation rate > 0 (High Resolution Swath)
dprrpf	area with DPR near surface precipitation rate > 0 (Matched swath)
kurppf	area with Ku dBZ > 10 dBZ in the column (Ku normal swath)
gpf	area with GMI precipitation rate > 0.1 mm/hr (Ku normal swath)
kuclconvf	area with Ku convective precipitation (Normal swath)
rgpf	area with either Ku precipitation rate > 0 or GMI precipitation rate > 0.1 mm/hr (Ku normal swath)
ggpf	area with GMI precipitation rate > 0.1 mm/hr (GMI swath)
gpctf	area with GMI 85 GHz Polarization corrected temperature < 250 K (GMI swath)

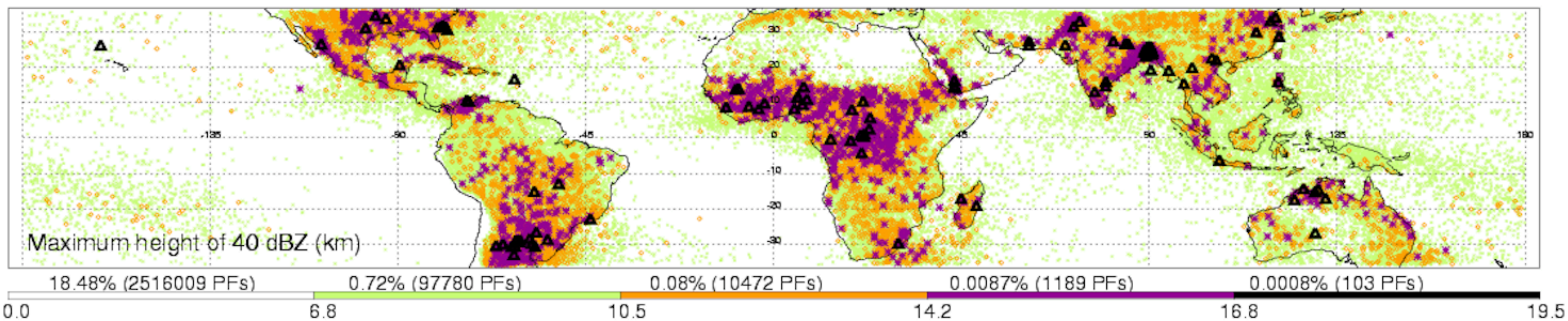
level-1	~240 MB per orbit	1yr ≈ 1.3 TB	
level-2	~1200 Kurpfs per orbit	1yr ≈ 1.1 GB	6.7 million features

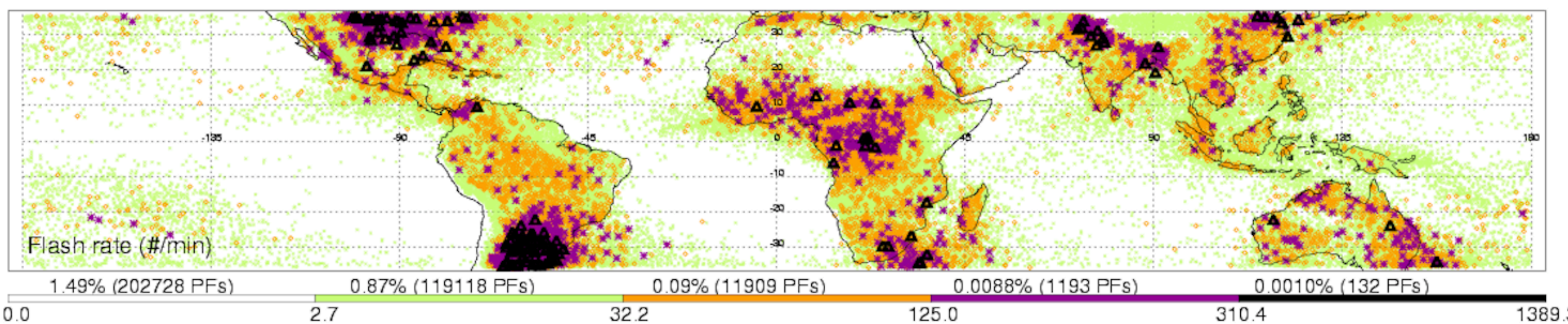
- All level 1 and 2 data are available at:

http://atmos.tamucc.edu/trmm/data/gpm/

The most intense thunderstorms on earth
TRMM

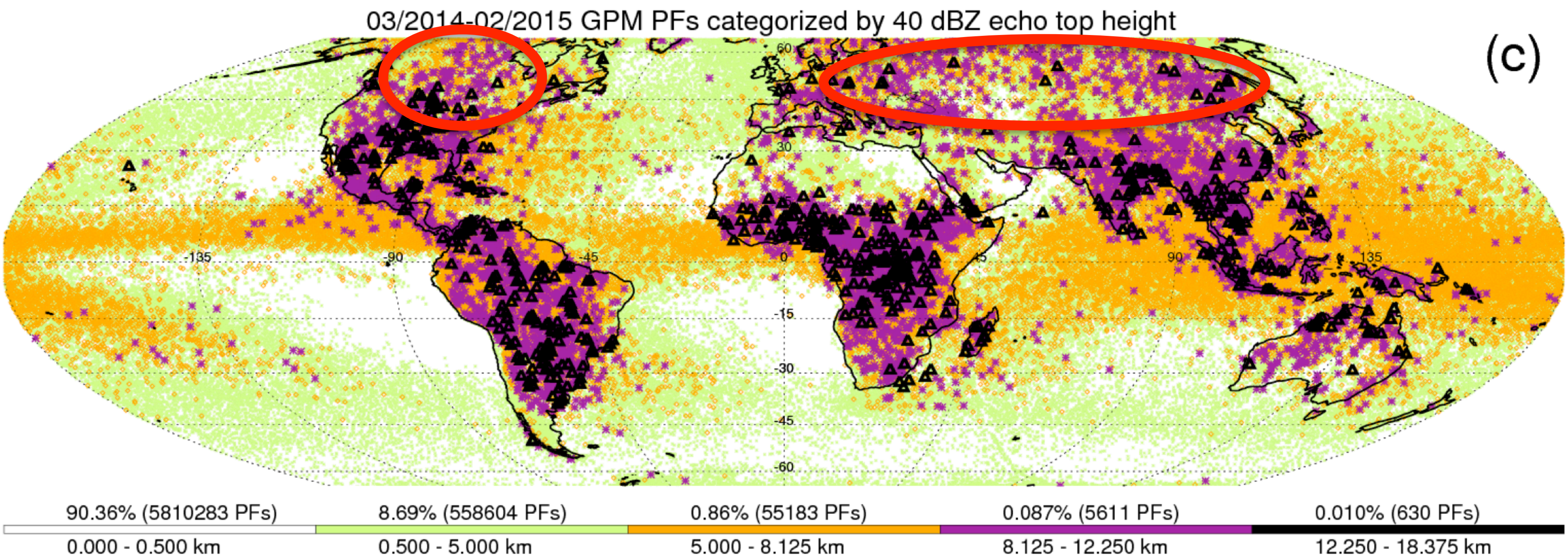
- Zipser et al. 2006 (BAMS)





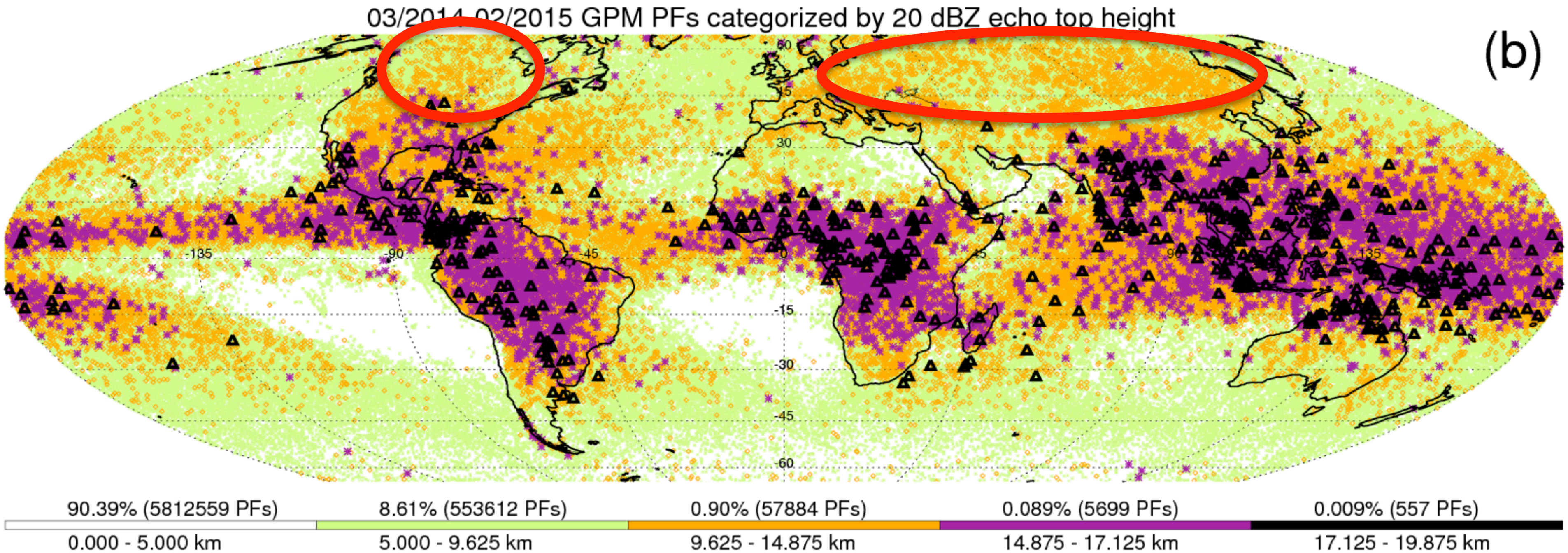
The most intense thunderstorms on Earth
GPM

- Liu and Zipser, 2015 (GRL)



more intense over land than over ocean

The tallest precipitation systems on Earth GPM



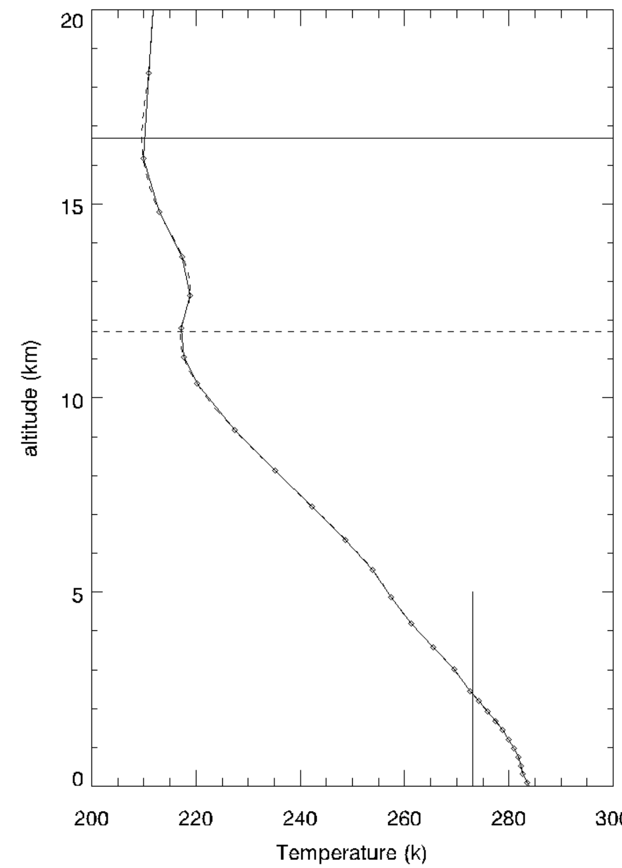
Taller in tropics
Taller over land in mid-high latitudes

Many literatures about overshooting convection in mid-high latitudes

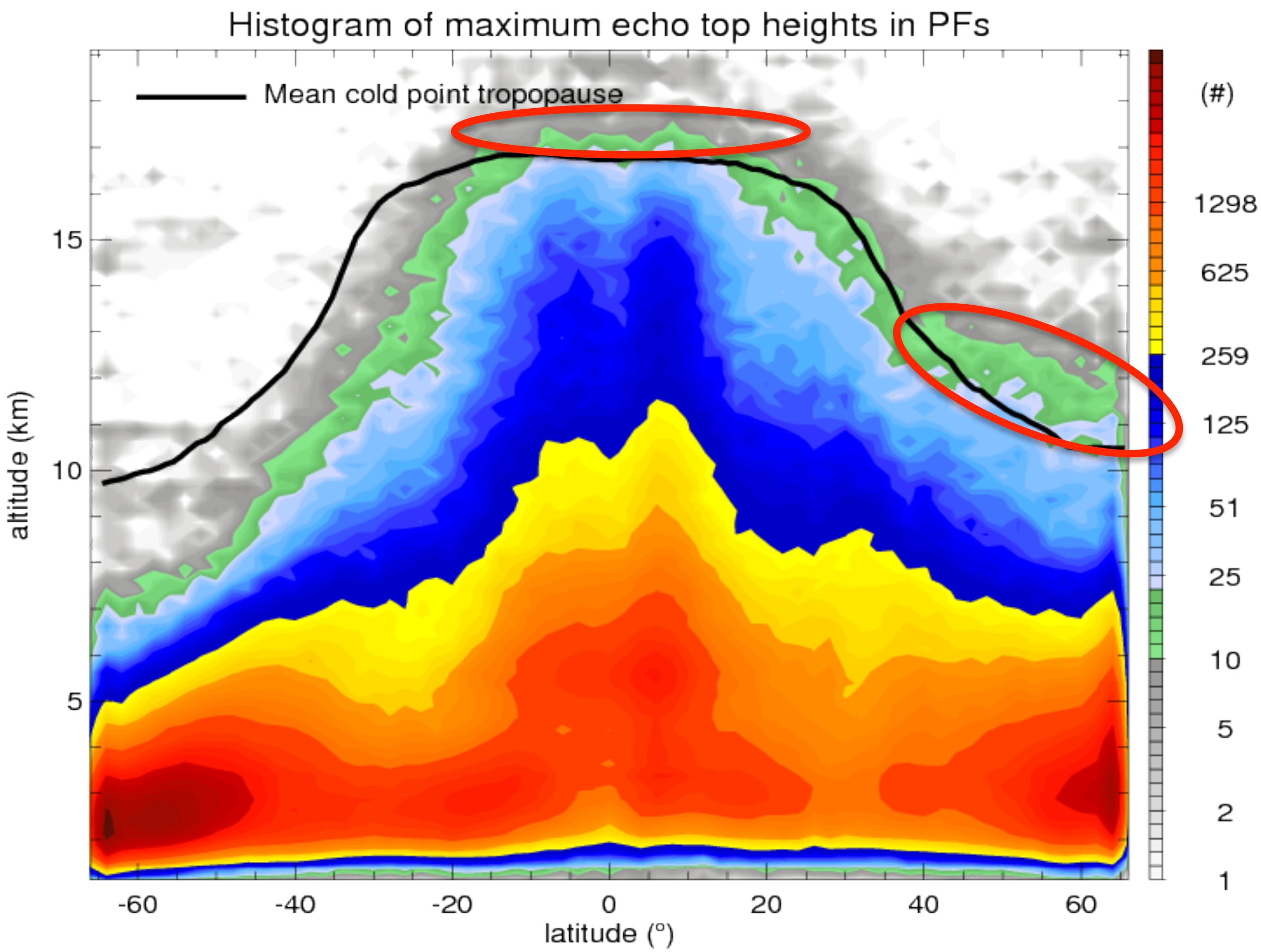
Where	Paper
North Dakota	Poulida et al. 1996, JGR
Europe	Hegglin et al. 2004, ACP
Summer time global	Dessler and Sherwood, 2004, JGR
Simulation	Mullendore et al. 2005, JGR
Simulation	Chagnon and Gray 2007, JGR
Europe	Setvak et al. 2008, Atmos. Res.
Europe	Bedka 2011, Atmos. Res.
Iowa, Simulation	Le and Gallus, 2012, JGR
Simulation	Tang et al. 2011, GRL
Nebraska & South Dakota	Homeyer et al. 2015, JGR

Define tropopause for each precipitation feature

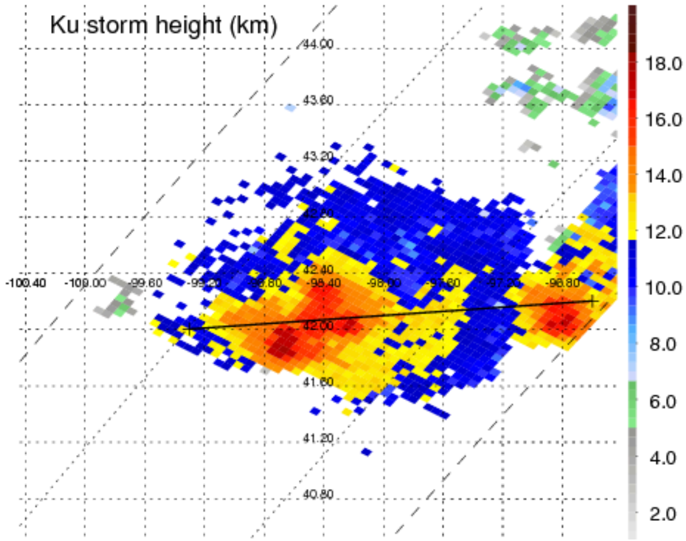
- ERA-Interim reanalysis
  - 6 hourly
  - 0.75^ox0.75^o
  - 37 vertical pressure levels
- Tropopause
  - Temperature profiles are spatially and temporally interpolated at each PF time and location.
  - Tropopause are identified as cold temperature "bumps" ($dT/dz=0$ & $T_z<T_{z\pm\Delta z}$) on temperature profiles between 5 and 20 km.
  - If there is no "bump" on the profile (rare, mainly near polar region), -99 is assigned.
  - The highest "bump" is used as the tropopause.



Histogram of the maximum Ku echo top heights in GPM PFs



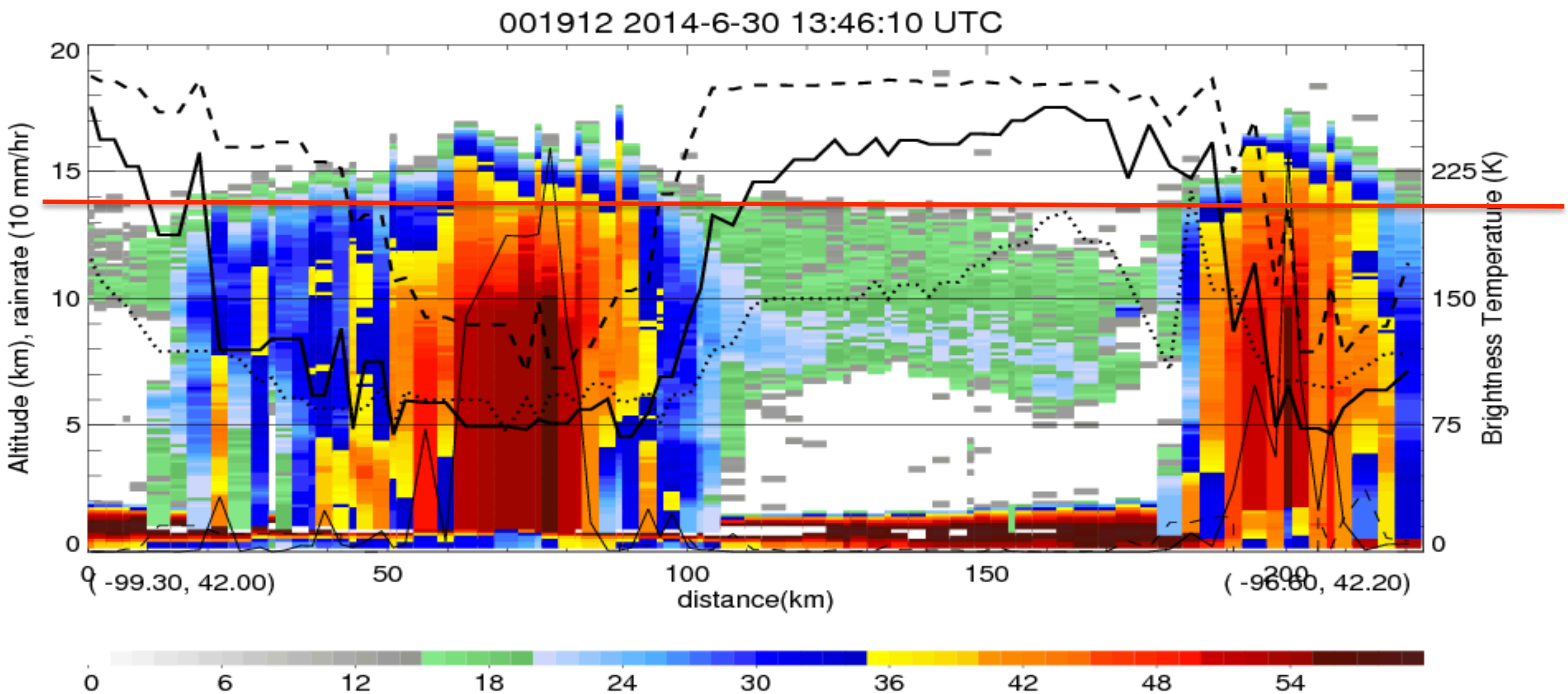
ERA-Interim reanalysis temperature profiles with 6 hourly 0.75°x 0.75° resolution are interpolated to PF times and locations, then the cold point tropopause heights are calculated for each PF



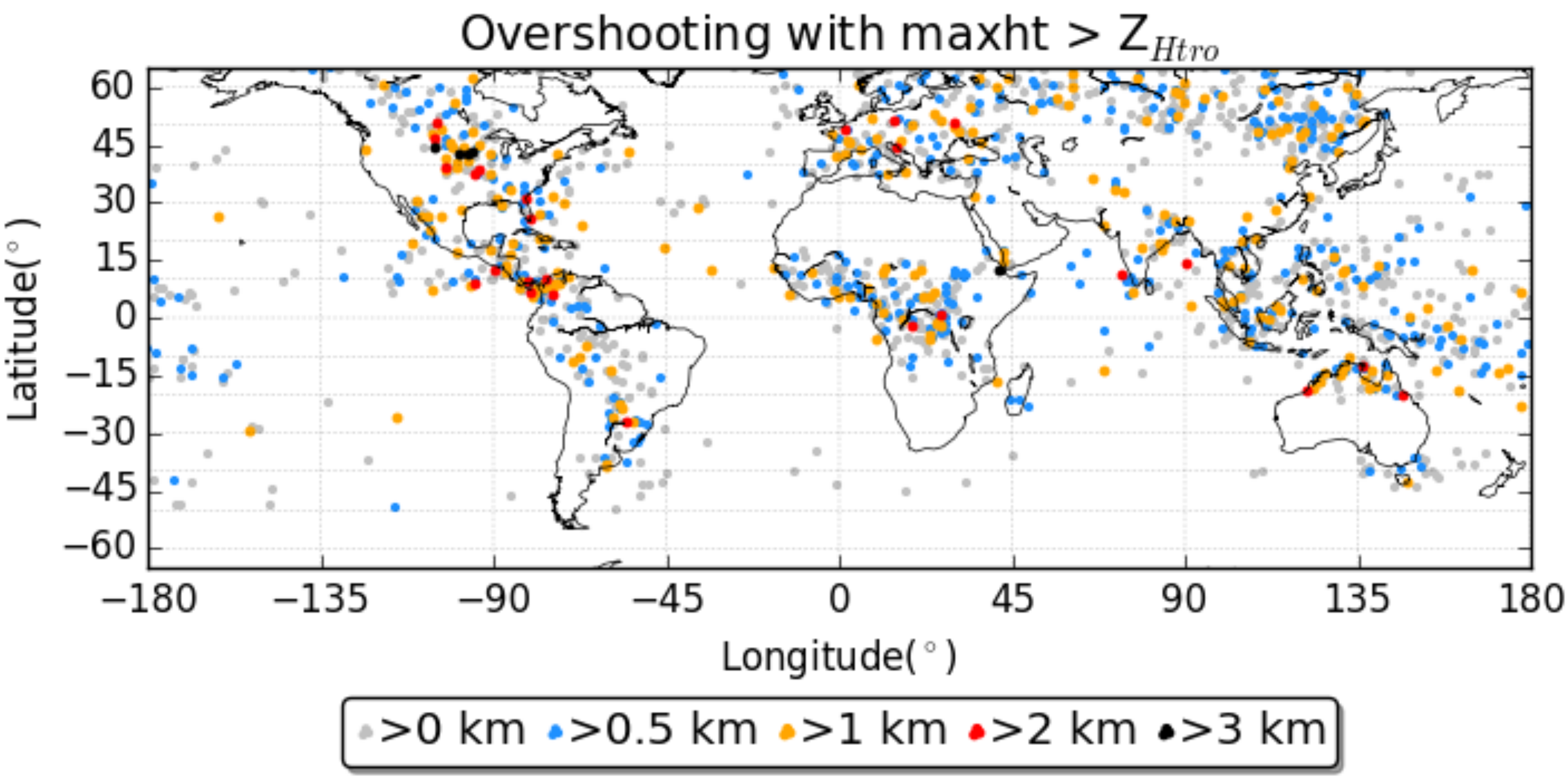
A storm over Nebraska

$Z_{tropopause}$= 13.7 (km)

$N_{tropopause}$=97 (# pixels) ≈ 2400 km^2

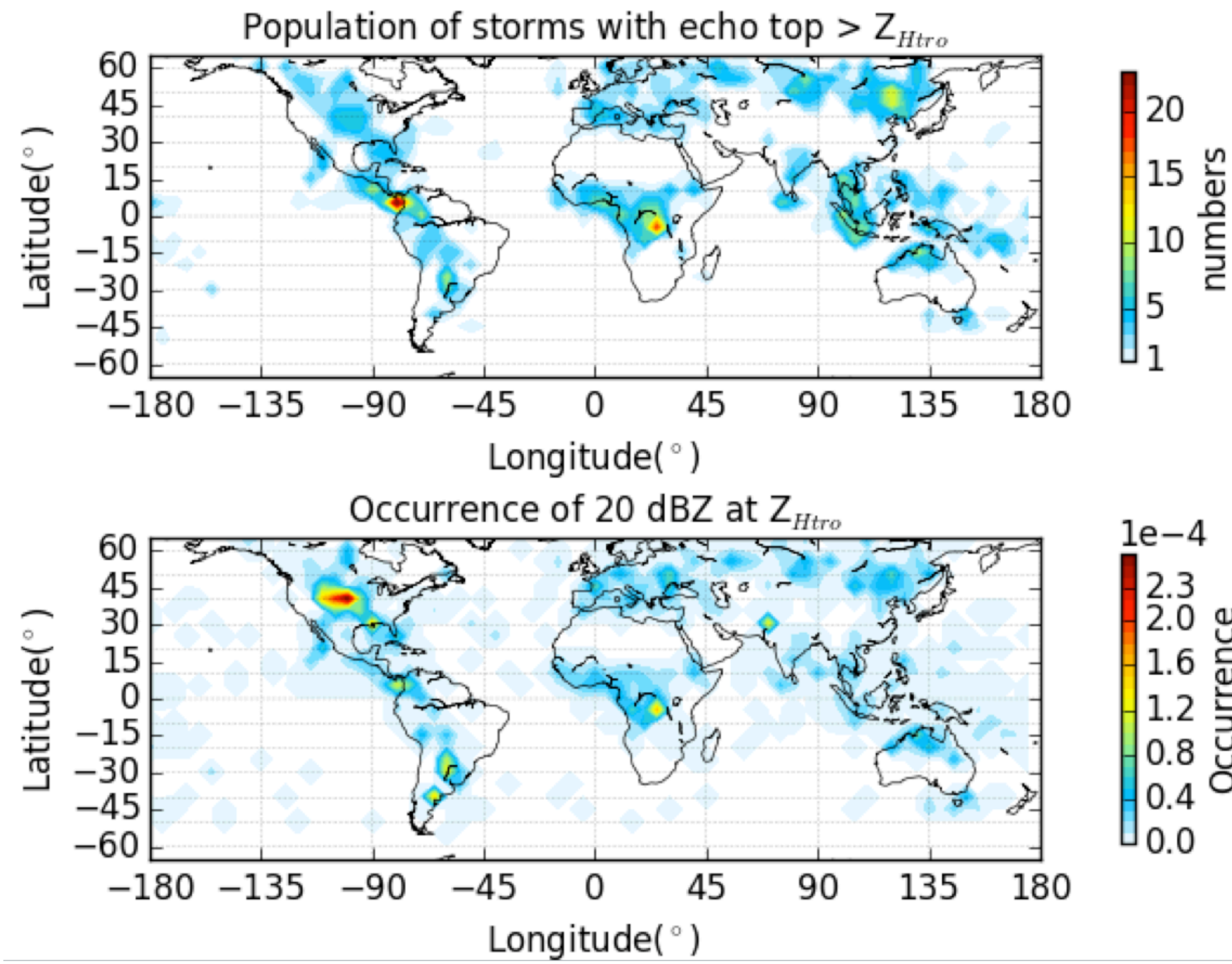


Locations of intense convection penetrating tropopause - GPM

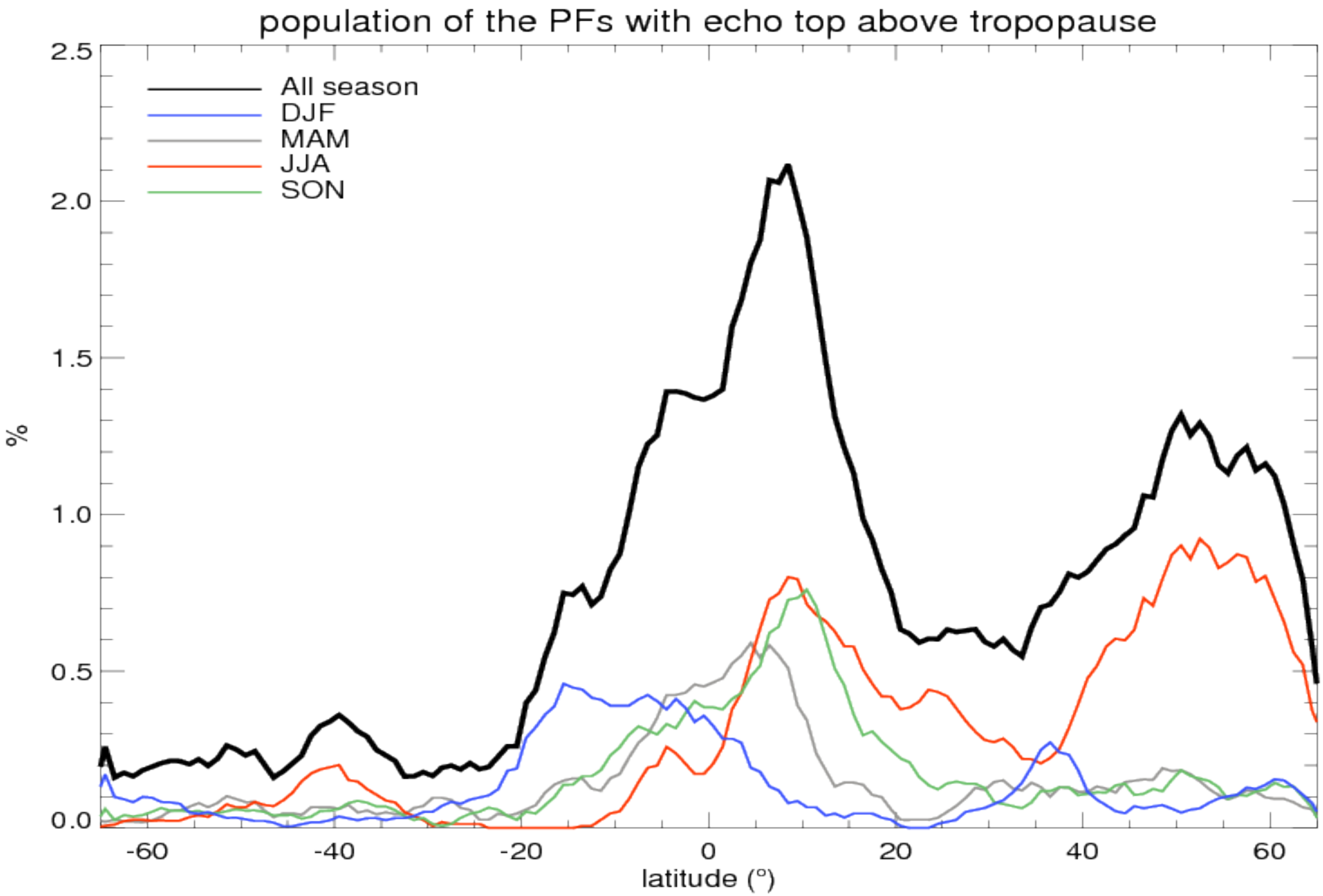


During 201403-201502, total 3516 PFs are found having echo top above tropopause

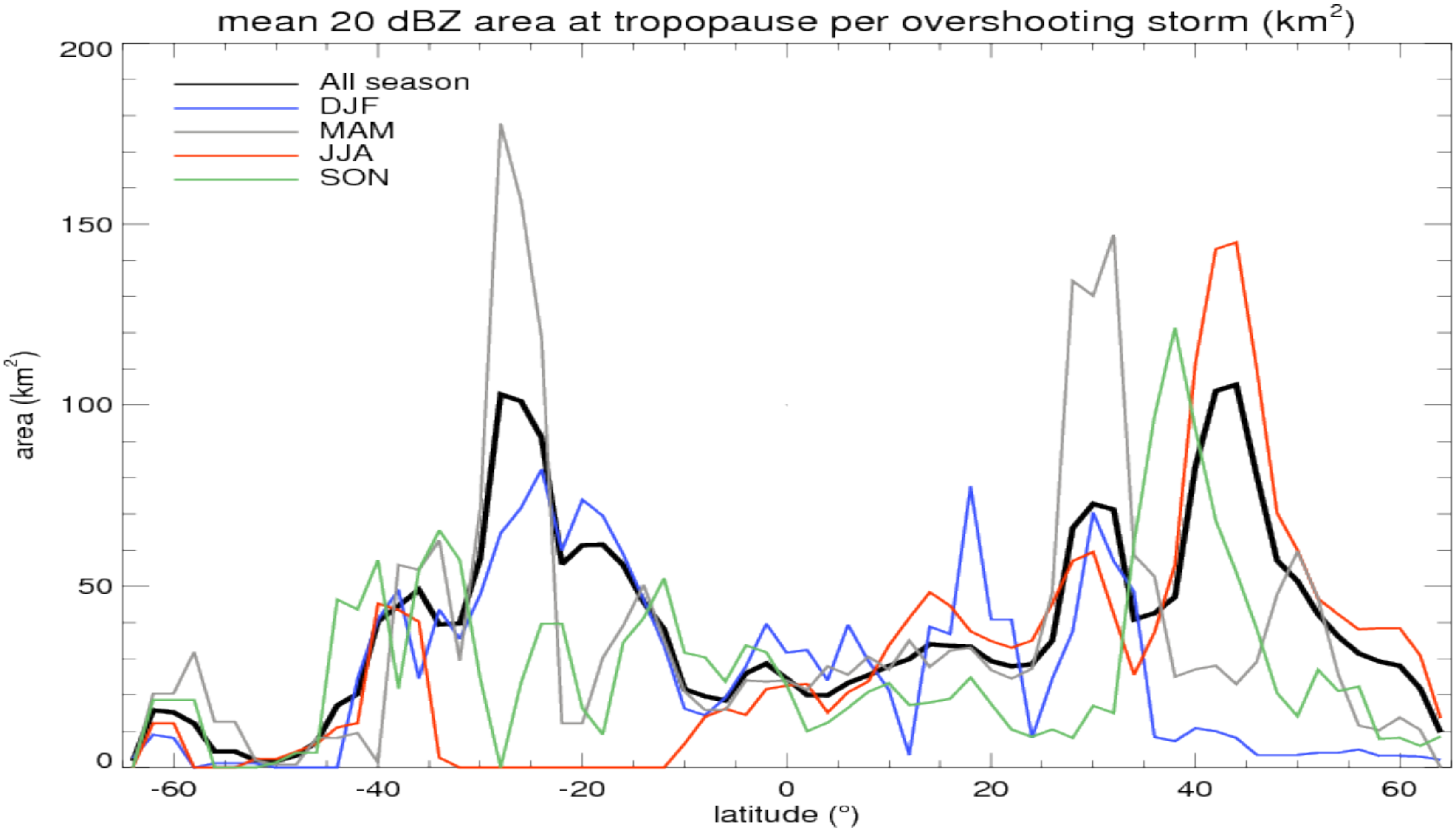
Global distributions of population of the overshooting storms and occurrence of 20 dBZ at tropopause height



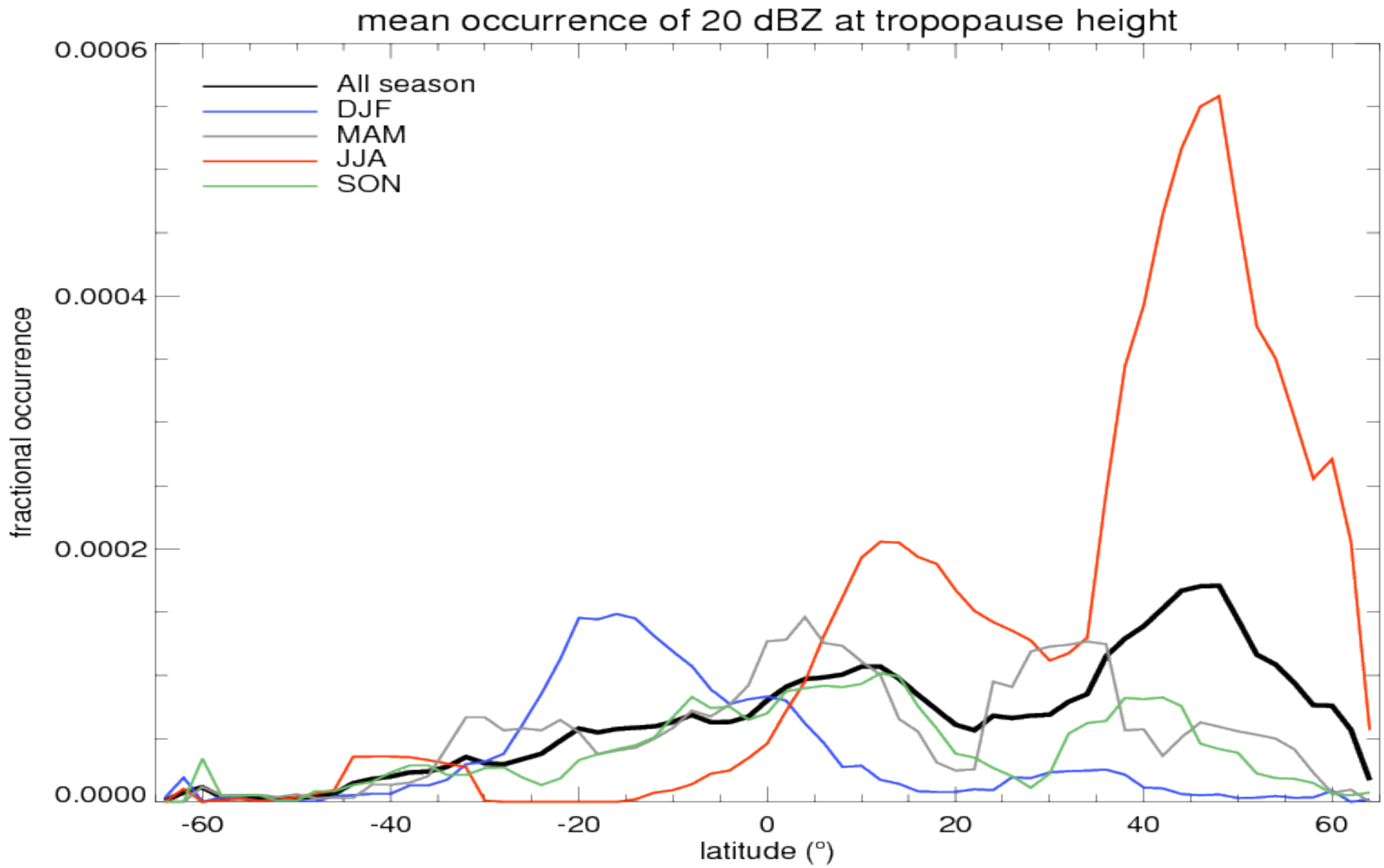
Population of the overshooting storms



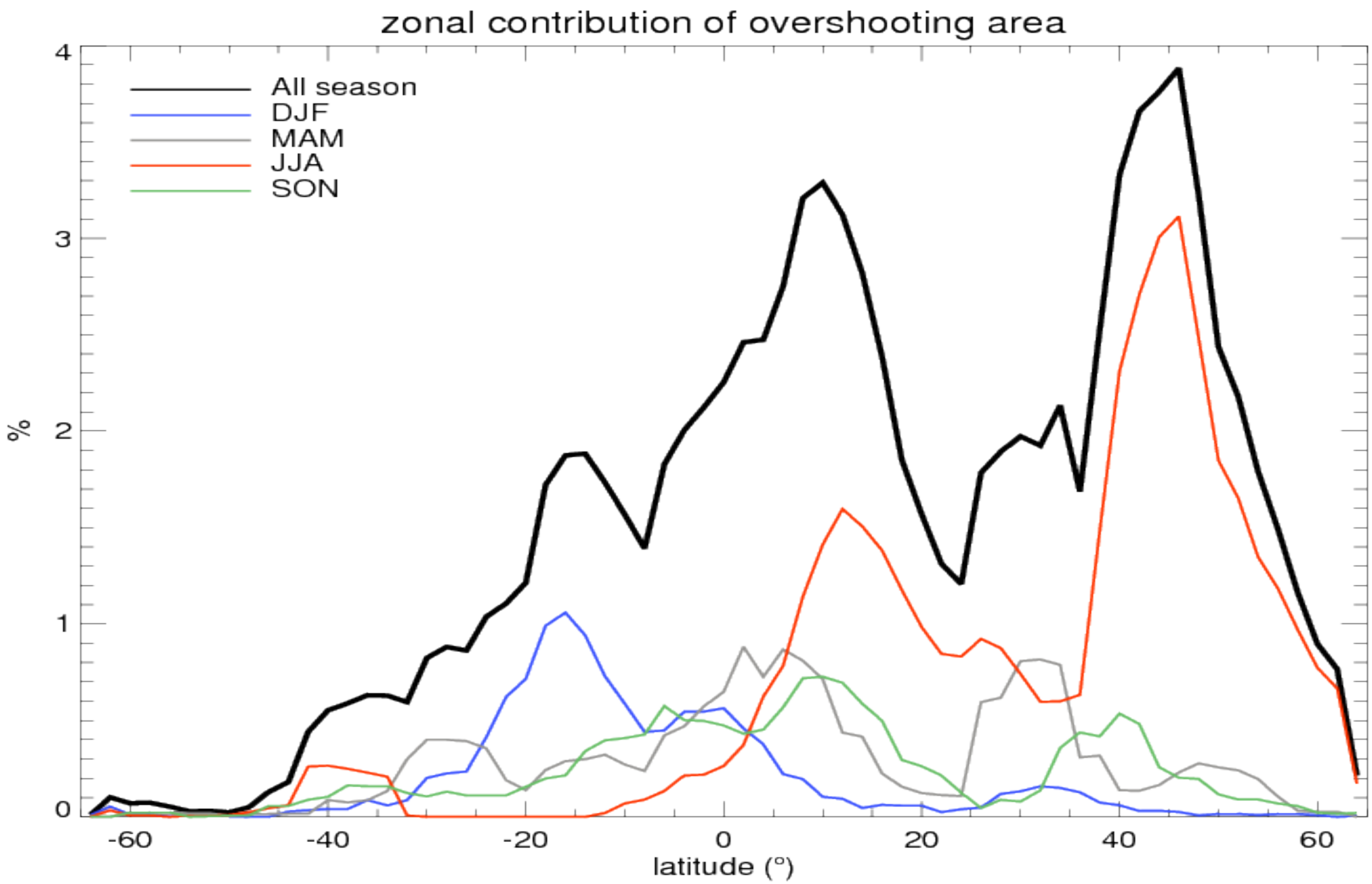
Mean overshooting area



occurrence of overshooting
(overshooting area per sample area)



Zonal contribution of overshooting indicated by 20 dBZ at tropopause height



Uncertainties in this analysis

- GPM Ku radar reflectivity
  - Horizontal resolution of GPM Ku radar footprint is close to 5 km, smaller scale overshooting could be overestimated by beam filling.
  - Though the radar product are still preliminary, random noises have been largely removed by using PF algorithm.
- Tropopause estimation
  - Temperature profiles are temporally interpolated from 6 hourly Era-Interim reanalysis
  - Uncertainties in tropopause estimation from ERA-Interim T profiles
  - The true tropopause might be influenced by deep convection at local scale
- Limited samples from only one year observation
  - Overshooting are rare events, more samples are needed to make statistics robust

Summary

- GPM PF database is a great tool to summarize invaluable information of the global convection and precipitation systems. The database is available to public at:

  http://atmos.tamucc.edu/trmm/data/gpm/

- There are many convection overshooting tropopause over land at mid and high latitudes. The overshooting area in these storms are larger than those in tropics. They may have significant contribution to the cross-tropopause transport.

Backup slides

Sample frequencies by Ku radar